Reply to "Comment on Strangeness -2 hypertriton"

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In this Reply we argue that the conclusions derived in Ref. [1] are questionable. In Ref. [2] we reported the following novelties: **1)** For the first time the Faddeev equations for the coupled $\Lambda\Lambda N - \Xi NN$ system have been solved. **2)** For the first time the previous formalism has been applied to the three-baryon strangeness -2 system with a single model for the interactions of the two-body subsystems. **3)** For this model, the $\Lambda\Lambda N$ system alone does not present a bound state, but the three-body system with quantum numbers $(I, J^P) = (\frac{1}{2}, \frac{1}{2}^+)$ is slightly below threshold.

Ref. [1] has taken alone the uncoupled $\Lambda\Lambda$ scattering length of the model of Ref. [2] (that we provided to the author), and has compared with results of three-body calculations of the $\Lambda\Lambda\alpha$ system in which either unrealistic separable potentials have been used for the two-body subsystems (Ref. [7] of the Comment) or the coupling $\Lambda\Lambda - N\Xi$ has been included only in an effective manner (Ref. [6] of the Comment). From this comparison Ref. [1] speculates about the results of the model of Ref. [2] for the binding energy of the ${}^{6}_{\Lambda\Lambda}$He. The binding energy obtained is attributed to the single piece picked up from Ref. [2].

The failure of the reasoning of Ref. [1] is demonstrated in the following table, where the binding energy of the strangeness -2 hypertriton ($B_{\hat{S}=-2}$) measured with respect to the NH threshold has been calculated for one of the models of Table III of Ref. [2] ($a^{N\Lambda}_{1/2,1} = -1.58$ fm, $a^{N\Lambda}_{1/2,0} = -2.48$ fm, signs are changed to use the convention of the comment) for different values of the uncoupled $\Lambda\Lambda$ scattering length but which describe equally well the available experimental data. These results rule out the arguments of Ref. [1] as we show next. Ref. [1] argues that the H dibaryon and the strangeness -2 hypertriton are both bound because the CCQM generates a $\Lambda\Lambda$ uncoupled scattering length of -3.3 fm and therefore since in ${}^{6}_{\Lambda\Lambda}$He only the uncoupled $\Lambda\Lambda$ scattering length acts, due to the Pauli principle, this model would lead to a very large ${}^{6}_{\Lambda\Lambda}$He binding energy which contradicts the experiment. However, as shown in the previous table, the existence of both a bound H dibaryon and a bound strangeness -2 hypertriton is compatible with a small $\Lambda\Lambda$ uncoupled scattering length which kills the argument of Ref. [1]. The Pauli principle acts strongly in ${}^{6}_{\Lambda\Lambda}$He because there is no room for more that four nucleons in S wave while in ${}^{3}_{\Lambda\Lambda}$H the full $N\Xi$ interaction can act in S wave. Thus, one cannot say that our YY-interaction model overbinds the ${}^{6}_{\Lambda\Lambda}$He until a calculation of that system using the model of Ref. [2] has been done.

$-a_{\Lambda\Lambda}$ (fm)	B_H (MeV)	$B_{\hat{S}=-2}$ (MeV)
3.3	6.928	0.577
2.3	6.191	0.640
1.3	4.962	0.753
0.5	3.250	0.927

The procedure of Ref. [1] contains other uncertainties that makes any final conclusion doubtful. Ref. [3] warned about the use of NN, $N\Lambda$ and $\Lambda\Lambda$ two-body interactions improved for the description of the ${}^{6}_{\Lambda\Lambda}$He to study other double Λ hypernuclei, as for example the ${}^{4}_{\Lambda\Lambda}$He. They demonstrate that a choice of the $N\Lambda$ interaction different to the references used in Ref. [1] gives binding for the ${}^{4}_{\Lambda\Lambda}$He [4] for a wide range of $\Lambda\Lambda$ scattering lengths [3]. This state would be unbound for the prescriptions used in Ref. [1]. Refs. [3, 5] also called the attention about the $\alpha\Lambda\Lambda$ three-body model used in Ref. [1], that might be inappropriate for deducing the $\Lambda\Lambda$ interaction in free space from the experimental information on $B_{LL}({}^{6}_{\Lambda\Lambda}\text{He})$. All these details are circumvented in Ref. [1].

Ref. [1] writes that "the latest HAL QCD lattice-simulation analysis locates the H dibaryon near the ΞN threshold.", quoting Ref. [6]. Immediately after this sentence one can read in Ref. [6] "This is however not a final conclusion due to various approximations about the SU(3) breaking ... currently underway lattice QCD simulations ... will eventually clarify the nature of the elusive H-dibaryon". Quadratic and linear extrapolations to the physical point, not performed in Ref. [6], using the results of the HAL QCD and NPLQCD collaborations have been presented in Ref. [7], allowing in both instances for a bound H-dibaryon or a near-threshold scattering state. This illustrates the actual uncertainties about the H dibaryon.

In summary, for all these reasons the conclusions of Ref. [1] are questionable.

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